

**POTENTIAL ENHANCED**  
**GREENHOUSE EFFECTS**

**STATUS AND OUTLOOK**

**DUANE G. LEVINE**

**PRESENTATION**  
**TO**  
**THE BOARD OF DIRECTORS**  
**OF**  
**EXXON CORPORATION**

**FEBRUARY 22, 1989**

THE GREENHOUSE EFFECT IS REAL...HAS EXISTED THROUGHOUT MAN'S HISTORY...AND IN FACT...WITHOUT IT, CURRENT LIFE COULD NOT EXIST. TODAY'S CONCERNS ARE ABOUT AN ENHANCEMENT OF THIS EFFECT DUE TO HUMAN ACTIVITIES. SO, I'LL REFER TO THESE CONCERNS COLLECTIVELY AS "POTENTIAL ENHANCED GREENHOUSE" OR PEG. IT HAS BEEN UNDER INTENSIVE SCIENTIFIC STUDY FOR OVER A DECADE BEFORE IT RECENTLY LEAPED TO THE FRONT PAGE.

IN SPITE OF THE RUSH BY SOME PARTICIPANTS IN THE GREENHOUSE DEBATE TO DECLARE THAT THE SCIENCE HAS DEMONSTRATED THE EXISTENCE OF PEG TODAY...I DO NOT BELIEVE SUCH IS THE CASE. ENHANCED GREENHOUSE IS STILL DEEPLY IMBEDDED IN SCIENTIFIC UNCERTAINTY, AND WE WILL REQUIRE SUBSTANTIAL ADDITIONAL INVESTIGATION TO DETERMINE THE DEGREE TO WHICH ITS EFFECTS MIGHT BE EXPERIENCED IN THE FUTURE.

### POTENTIAL ENHANCED GREENHOUSE (PEG)

#### What's Known/Not Known About the SCIENCE

- Chemistry/Physics
- Climate Models
- Data
- Projections

#### Who Are the Principal PLAYERS

- Programs
- Plans
- Perceptions

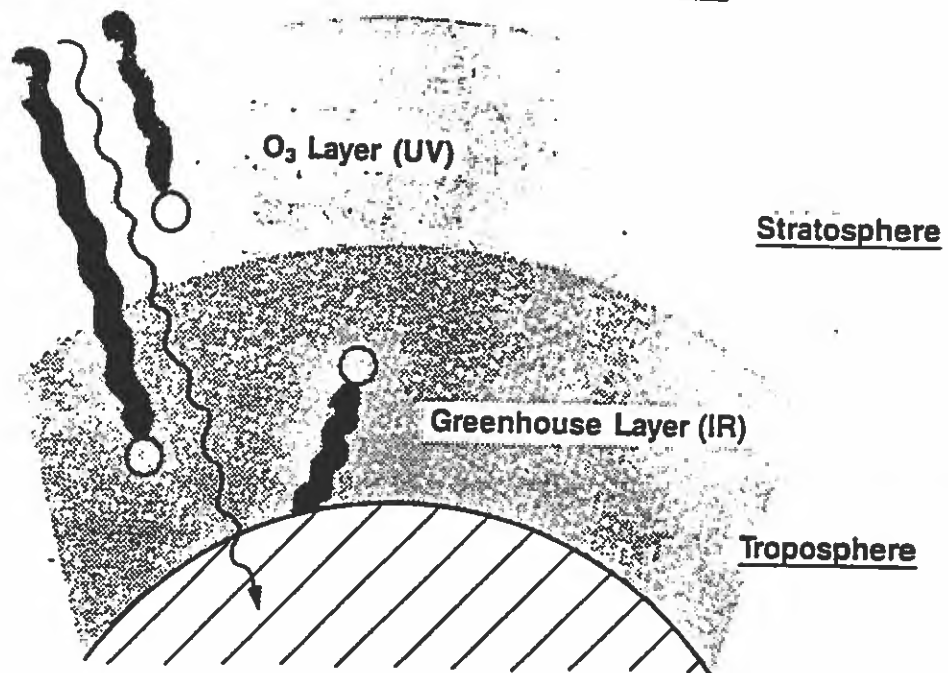
#### What's NEXT

SO THIS REVIEW WILL BEGIN WITH WHAT IS KNOWN AND NOT KNOWN ABOUT THE SCIENCE...FIRST THE ESSENTIAL CHEMISTRY AND PHYSICS...AND THEN PROCEED WITH A DESCRIPTION OF CLIMATE MODELS WHICH ARE USED TO PREDICT FUTURE POTENTIAL

EFFECTS. I'LL COVER THE HARD DATA AND THEN SUMMARIZE PROJECTED EFFECTS...BASED ON COMPLEX CLIMATE MODELS...WHICH...INCIDENTLY...HAVE YET TO BE VERIFIED.

HOWEVER, POLICY INITIATIVES ARE BEING ADVANCED NOW AND THEY COULD WELL OUT-PACE SCIENTIFIC PROGRESS. I'LL COVER THE CURRENT ROSTER OF PRINCIPAL PLAYERS IN THIS DEBATE, OUTLINE THEIR PROGRAM AND PLANS, AND SUMMARIZE SOME OF THEIR MOST VISIBLE PERCEPTIONS. FINALLY, I'LL TRY A GLIMPSE AT WHAT'S NEXT.

### GLOBAL ATMOSPHERIC CONCERNS



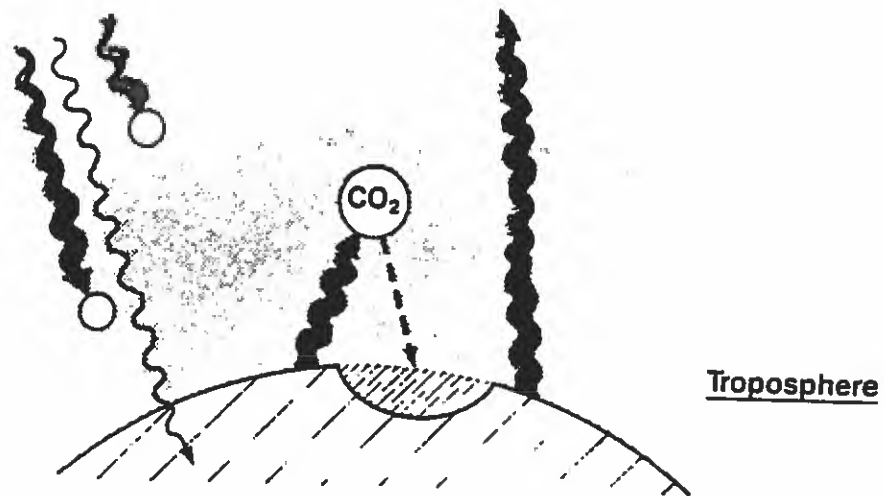
TO PUT PEG IN PERSPECTIVE, LET'S START WITH A GENERAL MODEL OF THE EARTH'S ATMOSPHERE AND 2 OF THE CURRENT MAJOR GLOBAL ATMOSPHERIC CONCERNS. ON THE LEFT, SOLAR RADIANT ENERGY IS REPRESENTED BY A BEAM RANGING FROM INFRARED (IR IN RED) TO ULTRAVIOLET (UV IN BLUE)...WITH THE BULK OF THE ENERGY IN THE VISIBLE RANGE SHOWN IN YELLOW. MOST OF THE

UV IS PICKED UP IN THE O<sub>3</sub> LAYER IN THE STRATOSPHERE OR UPPER ATMOSPHERE (WHICH EXTENDS APPROXIMATELY 15-50 KM ABOVE THE EARTH'S SURFACE). THIS, OF COURSE, REVEALS THE CONCERN OVER DETERIORATION OF THIS LAYER BY MAN-MADE CHLOROFLUOROCARBONS (CFCs) WHICH CAN ATTACK O<sub>3</sub> AND REDUCE ITS CONCENTRATION IN THE STRATOSPHERE. SUCH DETERIORATION WOULD ALLOW MORE UV TO PENETRATE THE ATMOSPHERE AND IMPACT LIFE ON THE EARTH'S SURFACE. PROTECTION OF THIS O<sub>3</sub> LAYER BY REDUCING CFCs IS THE GOAL OF THE RECENT MONTREAL PROTOCOLS.

MOST OF THE IR PENETRATES THE STRATOSPHERE AND IS ABSORBED BY GREENHOUSE GASES IN THE LOWER ATMOSPHERE OR TROPOSPHERE. THIS, OF COURSE, HELPS WARM THE EARTH. THE BULK OF THE RADIANT ENERGY REACHING THE EARTH IS ABSORBED IN THE VISIBLE RANGE (SHOWN IN YELLOW)...DIRECTLY WARMING THE EARTH. THE RE-EMITTED ENERGY...AND THIS IS MOST IMPORTANT...IS CONCENTRATED IN THE IR RANGE AND THAT ADDS TO THE AMOUNT OF IR IN THE TROPOSPHERE.

OVERALL, THEN, THE UPPER ATMOSPHERE IS DOMINATED BY UV...AND O<sub>3</sub> LAYER PROTECTION IS THE ISSUE...WHILE THE LOWER ATMOSPHERE IS DOMINATED BY IR AND GREENHOUSE-TYPE PROCESSES... WITH CLIMATE CHANGE AS THE ISSUE.

## ATMOSPHERIC GREENHOUSE EFFECT

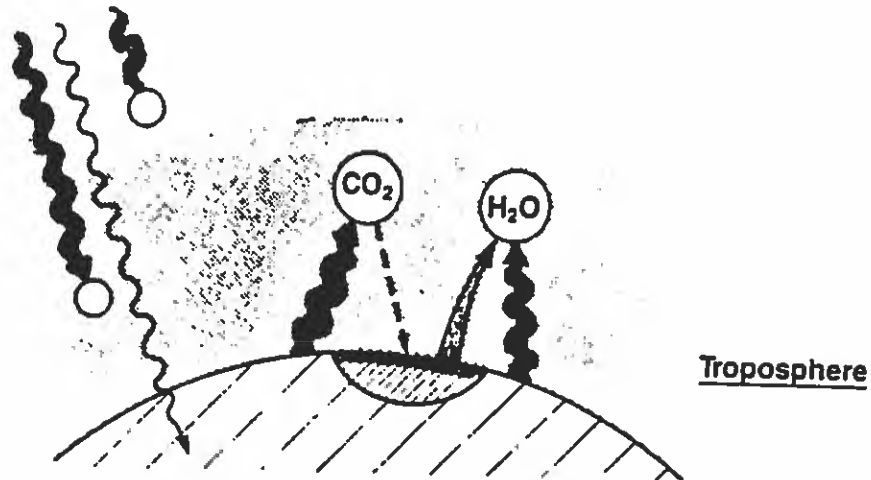


Troposphere

- Earth Concentrates IR

WE CAN GO A LITTLE DEEPER ON GREENHOUSE TO HIGHLIGHT 2 KEY ASPECTS WHICH DETERMINE ITS OVERALL EFFECTIVENESS. AGAIN...THE BAND OF SOLAR RADIATION IS DEPICTED ON THE LEFT. AS MENTIONED, MOST OF THE INCIDENT VISIBLE SOLAR RADIATION (IN YELLOW) IS ABSORBED BY THE EARTH'S SURFACE AND RE-EMITTED ALMOST EXCLUSIVELY AS IR (IN RED). IF THIS RE-EMITTED IR ENCOUNTERS GREENHOUSE GASES...LIKE CO<sub>2</sub>...WHOSE PROPERTIES FAVOR IR ABSORPTION...THEY ABSORB IT...LEVERAGING THE IR WARMING...INDICATED BY THE DASHED LINE. WHEN NO GREENHOUSE GASES ARE ENCOUNTERED, THE RE-EMITTED IR ESCAPES TO SPACE. THUS, THE EARTH SERVES TO CONCENTRATE IR IN THE TROPOSPHERE AND GREENHOUSE GASES CONVERT IT

## ATMOSPHERIC GREENHOUSE EFFECT



Troposphere

- Earth Concentrates IR
- Water Vapor Increases IR Trapping Effect

TO HEAT. NOW...THIS ADDITIONAL HEATING PROMOTES MORE WATER VAPORIZATION AND WATER VAPOR ITSELF IS A VERY EFFECTIVE GREENHOUSE GAS. IN FACT, IT IS ABOUT 3 TIMES MORE EFFECTIVE THAN CO<sub>2</sub>. IT'S REALLY THE WATER VAPOR THAT DOES MOST OF THE JOB. THIS LATTER POINT IS SIGNIFICANT BECAUSE ANY GREENHOUSE GAS...INCLUDING TRACE GREENHOUSE GASES LIKE CFCs, CH<sub>4</sub>, HALOGENS, N<sub>2</sub>O, AND O<sub>3</sub> IN THE TROPOSPHERE...CAN TRIGGER THE ADDITIONAL WATER VAPOR LEVERAGING EFFECT.

**THIS INSIGHT ALSO EXPOSES THE ENORMOUS DIFFERENCES BETWEEN O<sub>3</sub> LAYER PROTECTION AND ENHANCED GREENHOUSE...**

- **THEY OCCUR IN DIFFERENT PARTS OF THE ATMOSPHERE.**
- **THEY INVOLVE DIFFERENT PHYSICS AND CHEMISTRY.**
- **THEY HAVE DIFFERENT EFFECTS ON LIFE.**
- AND**
- **WHEREAS O<sub>3</sub> LAYER DETERIORATION IS CURRENTLY TRACED TO A SINGLE FAMILY OF MAN-MADE CHEMICALS...GREENHOUSE INCLUDES THE LIFE CYCLE GASES CO<sub>2</sub> AND H<sub>2</sub>O WITH MANY NATURAL SOURCES AND SINKS.**

**FINALLY, I SHOULD ACKNOWLEDGE THAT THERE ARE SOME INTERACTIONS BETWEEN O<sub>3</sub> LAYER PROTECTION AND GREENHOUSE IN THAT O<sub>3</sub> AND CFCs ARE BOTH GREENHOUSE GASES AND O<sub>3</sub> CAN REACT WITH CERTAIN OTHER GREENHOUSE TROPOSPHERIC GASES.**

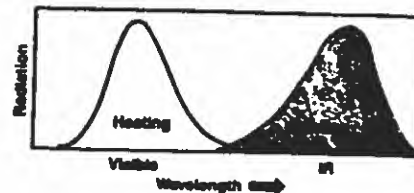
**EXACTLY HOW THE GREENHOUSE GASES DETERMINE GLOBAL HEAT OR ENERGY BALANCE...AND HOW THE FLOW OF ENERGY IN AND OUT OF THE EARTH'S ATMOSPHERE DRIVES OUR CLIMATE IS DESCRIBED IN THE NEXT 2 FIGURES...FIRST, THE GLOBAL ENERGY BALANCE...**

## GREENHOUSE GASES & GLOBAL HEAT BALANCE

- Radiation Balance Regulates Global Temperature

Cooling Depends On:

Temperature  
Atmospheric Composition



VIEWS FROM SPACE, THE EARTH MUST BE IN ENERGY EQUILIBRIUM. THAT MEANS...HEAT FLOWING IN FROM SOLAR RADIATION (SHOWN IN YELLOW) MUST EQUAL HEAT RE-EMITTED BY THE EARTH (SHOWN IN RED). THIS PLOT SHOWS THE RADIANT ENERGY IN AND OUT AS A FUNCTION OF WAVE LENGTH...YELLOW SOLAR HEATING IN THE VISIBLE RANGE AND RED EARTH COOLING IN THE IR RANGE...ALTHOUGH THE SHAPES OF THE CURVES ARE DIFFERENT AND THE RADIATION IS AT QUITE DIFFERENT WAVELENGTHS, THE FACT IS THAT THE AREAS UNDER THE CURVES ARE EQUAL. THIS EQUALITY INDICATES THE BALANCE BETWEEN TOTAL RADIATIVE HEATING AND COOLING.

NOW, INCOMING SOLAR RADIATION...IS ESSENTIALLY A CONSTANT OVER TIME. HOWEVER, RADIANT COOLING DEPENDS ON THE EARTH'S TEMPERATURE AND ATMOSPHERIC COMPOSITION. THE COOLING CURVE IS SHOWN IN MORE DETAIL IN THE FIGURE. COMPARED WITH THE SOMEWHAT

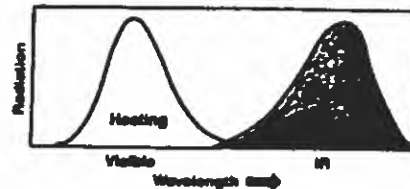


## GREENHOUSE GASES & GLOBAL HEAT BALANCE

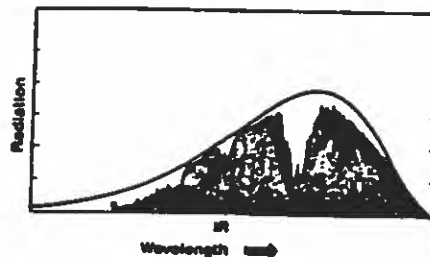
- Radiation Balance Regulates Global Temperature

Cooling Depends On:

Temperature  
Atmospheric Composition



- Greenhouse Gases Selectively Trap IR Radiation



- Existing Greenhouse Produces 60°F Surface Warming  
— Without IR Greenhouse Earth Would Be Largely Frozen

IDEALIZED, SMOOTH COOLING CURVE SHOWN ABOVE...HERE, IN FINER DETAIL, WE SEE THE EFFECT OF GREENHOUSE GASES. THE CLEAR AREA BENEATH THE CURVE SHOWS THE ABSORPTION OF IR RADIANT ENERGY RE-EMITTED BY THE EARTH AT PARTICULAR WAVELENGTHS. QUITE OBVIOUS ARE THE STRONG ABSORPTION FEATURES PRODUCED BY CO<sub>2</sub> AND O<sub>3</sub>. WATER VAPOR, THE MOST POWERFUL GREENHOUSE GAS, ABSORBS AT ALL WAVE LENGTHS. THE TOTAL GREENHOUSE EFFECT DEPENDS ON THE NATURE (MOLECULAR STRUCTURE) AND NUMBER (ATMOSPHERIC CONCENTRATION) OF ALL GREENHOUSE MOLECULES.

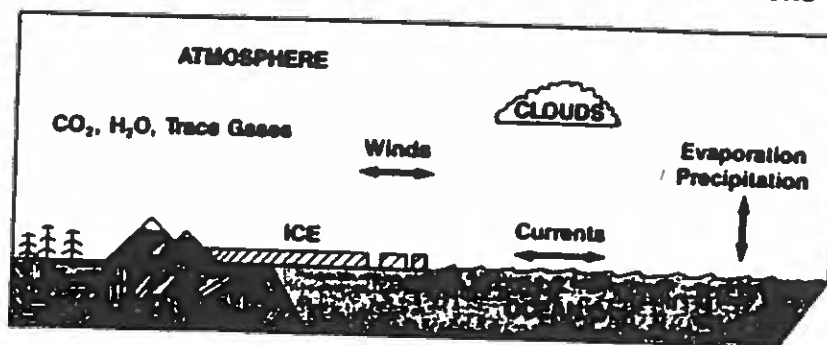
SINCE THE SOLAR HEATING INPUT REMAINS CONSTANT...WHILE THE GREENHOUSE GASES HAVE ABSORBED SOME OF THE IR COOLING, THE EARTH MUST INCREASE ITS TEMPERATURE TO MAINTAIN EQUILIBRIUM RADIANT HEAT OUTPUT. IN MODERN

CLIMATE, THE EXISTING GREENHOUSE PRODUCES A 600F SURFACE WARMING. WITHOUT THIS EFFECT ...THE EARTH WOULD BE LARGELY FROZEN AND LIFE AS WE KNOW IT COULD NOT EXIST.

NOW FOR THE SECOND FIGURE...DESCRIBING HOW THE FLOW OF ENERGY IN THE ATMOSPHERE DRIVES CLIMATE.

### ELEMENTS OF CLIMATE

- Climate Response is Governed By Complex Interactions

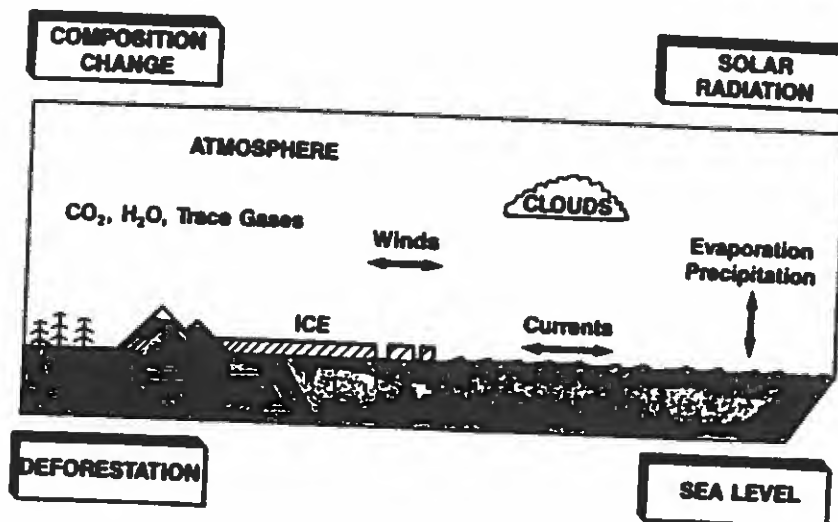


ALTHOUGH OUR TOTAL ATMOSPHERE VIEWED FROM OUTSIDE SPACE MUST BE IN EQUILIBRIUM WITH RESPECT TO SOLAR HEATING AND EARTH COOLING, WIDE VARIATIONS IN HEATING CAN EXIST INSIDE OUR ENVIRONMENT. ONCE HEAT IS ABSORBED, IT SETS IN MOTION ALL THE COMPLEX PROCESSES WHICH SHAPE OUR CLIMATE. THE PURPOSE OF CLIMATE MODELS IS TO ATTEMPT TO SORT-OUT THESE EFFECTS. CLIMATE REFERS TO THE AVERAGE TREND OF WEATHER, INCLUDING VARIABILITY. DYNAMIC EFFECTS OF WINDS AND CURRENTS CONTROL GLOBAL CLIMATE BY TRANSPORTING HEAT OVER LARGE DISTANCES. IMPORTANT FEATURES OF AVERAGE CLIMATE INCLUDE EVAPORATION/PRECIPIATION AND CLOUD FORMATION...ALL OF WHICH DISPLAY ENORMOUS VARIABILITY.

THE DIFFICULTY IN PREDICTING CLIMATE CHANGE...THEN...IS NOT ASSOCIATED WITH GREENHOUSE GAS IR RADIATIVE PROPERTIES...BUT RATHER WITH CAPABILITIES TO UNDERSTAND AND MODEL THE RESPONSE OF CLIMATE. FOR EXAMPLE, LET'S BRIEFLY OUTLINE THE EFFECTS OF A COMPOSITIONAL CHANGE...INCREASING CO<sub>2</sub>...ON CLIMATE.

### ELEMENTS OF CLIMATE

- Climate Response is Governed By Complex Interactions



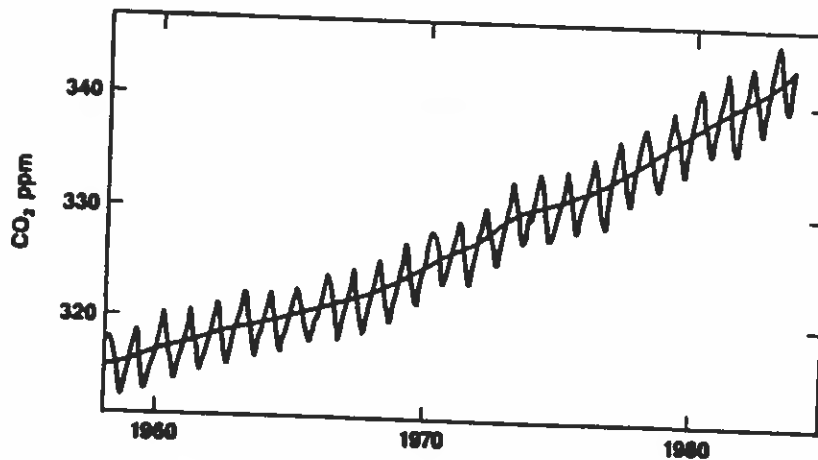
THE ADDED CO<sub>2</sub> TRAPS SOME ADDITIONAL HEAT...WARMING THE ATMOSPHERE BY A SMALL AMOUNT. THIS TRIGGERS OTHER CHANGES. MODELS SHOW THAT A WARMER ATMOSPHERE BECOMES MORE MOIST...WITH MORE WATER VAPOR (A MORE POWERFUL GREENHOUSE GAS) CAUSING EVEN MORE WARMING. BUT DEPENDING ON CLIMATE RESPONSE...AN INCREASE IN MOISTURE MAY INCREASE CLOUD FORMATION...SHIELDING PARTS OF THE EARTH'S SURFACE FROM DIRECT SOLAR RADIATION, AND...PERHAPS...COMPENSATING FOR THE ADDITIONAL GREENHOUSE WARMING. OTHER EFFECTS NOT WELL UNDERSTOOD...LIKE OCEAN

**CURRENTS...CAN ALSO AMPLIFY OR REDUCE WARMING.**

**IN ADDITION TO ATMOSPHERIC COMPOSITION CHANGES, WE ARE ALSO CONCERNED TODAY WITH CLIMATE CHANGES FORCED BY MASSIVE DEFORESTATION. THIS DESTRUCTION ADDS TO THE CO<sub>2</sub> LOADING TO THE ATMOSPHERE AND REMOVES SOME CO<sub>2</sub> SINK CAPACITY THROUGH PHOTOSYNTHESIS.**

**FINALLY, OVER VERY LONG GEOLOGICAL TIME SCALES...CONTINENTAL DRIFT, SHIFTS IN THE EARTH'S ORBIT, AND OTHER SOLAR VARIATIONS...MAY CAUSE CHANGES IN SEA LEVEL AND SOLAR RADIATION WHICH CAN HAVE ENORMOUS EFFECTS ON CLIMATE. BUT THESE ARE USUALLY NOT PART OF CURRENT PEG PREDICTIONS.**

### **HISTORICAL RECORD OF ATMOSPHERIC CO<sub>2</sub> VARIATION**



- **Measurements Confirmed in Detail**
- **Increase 3 GTON Carbon Per Year**
- **Pre-Industrial CO<sub>2</sub> Level 270 ppm (28% Growth)**

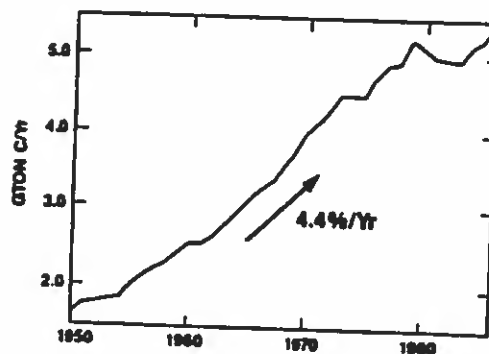
NOW I'LL COVER THE HARD DATA WE HAVE ON PEG. FIRST, THE FAMOUS MAUNA LOA (HAWAII) RECORDINGS SHOWING THE INCREASING CONCENTRATION OF ATMOSPHERIC CO<sub>2</sub>. OBSERVATIONS AT THE SCRIPPS INSTITUTE BEGAN IN 1958 AS PART OF THE INTERNATIONAL GEOPHYSICAL YEAR. THE DATA SHOW A STEADY INCREASE IN CO<sub>2</sub> WITH AN OBVIOUS ANNUAL OSCILLATION. THE PERIODIC VARIATION OCCURS BECAUSE CO<sub>2</sub> IS DRAWN DOWN DURING THE GROWING SEASON AND RELEASED IN THE FALL AND WINTER. SINCE 1958, CO<sub>2</sub> HAS RISEN FROM 315 PPM TO ABOUT 345 PPM, TODAY.

THESE MEASUREMENTS HAVE BEEN CONFIRMED ( $\pm 1$  PPM) IN GREAT DETAIL AT SITES FROM THE NORTH POLE TO ANTARCTICA. CO<sub>2</sub> MIXES RAPIDLY IN THE ATMOSPHERE, SO RESULTS ON THE AVERAGE GROWTH OF CO<sub>2</sub> ARE SIMILAR ACROSS THE GLOBE.

THE NET ACCUMULATION RATE OF CARBON IN THE ATMOSPHERE IS ABOUT 3 GIGATONS (BILLIONS OF METRIC TONS) PER YEAR CORRESPONDING TO THIS GROWTH.

FROM MEASUREMENTS OF AIR BUBBLES TRAPPED IN GLACIAL ICE CORES, IT IS ESTABLISHED THAT THE RECENT BUILDUP OF CO<sub>2</sub> BEGAN WITH THE INDUSTRIAL ERA. IN THE MID 1800S THE CO<sub>2</sub> LEVEL WAS ABOUT 270 PPM ( $\pm 10$  PPM). CO<sub>2</sub> GROWTH IS ABOUT 28% SINCE THEN.

## HISTORICAL RECORD OF FOSSIL FUEL CO<sub>2</sub> EMISSION



- Growth Resumed Following Reversal in Mid 70s  
— Growth Rate Again at Historical Levels 4%/Yr
- If Growth Persists, CO<sub>2</sub> Doubling Occurs Sooner  
— By Several Decades

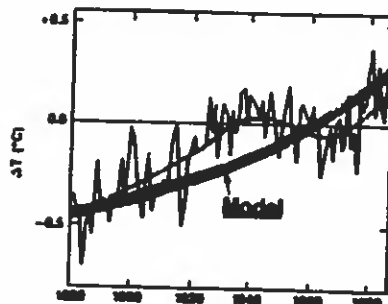
THE NEXT DATA SHOW CO<sub>2</sub> EMISSION FROM FOSSIL FUELS BETWEEN 1950 AND TODAY. THE UNITS ARE BILLIONS OF TONS (GTON) OF CARBON PER YEAR. THERE ARE TWO IMPORTANT POINTS FROM THIS FIGURE:

FIRST NOTE THAT MODERN EMISSION RATES ARE MUCH LARGER THAN THE RATE OF ACCUMULATION OF CO<sub>2</sub> IN THE ATMOSPHERE. RECALL THAT ATMOSPHERIC CO<sub>2</sub> IS GROWING BY ABOUT 3 GTON/YR. FOSSIL FUEL EMISSIONS TODAY ARE ABOUT 5 GTON, AND DEFORESTATION IS THOUGHT TO ADD ABOUT 1 GTON. EXACT VALUES FOR DEFORESTATION ARE CONTROVERSIAL. ESTIMATES RANGE FROM LESS THAN 1 TO OVER 2 GTON PER YEAR. NONETHELESS, ONLY ABOUT HALF THE EMITTED CO<sub>2</sub> STAYS IN THE ATMOSPHERE. THE OTHER HALF IS THOUGHT TO BE ABSORBED INTO THE OCEANS. IT IS ALSO TRUE THAT PLANTS GROW BETTER IN AN ATMOSPHERE ENRICHED IN CO<sub>2</sub>. THAT HAS LED

SOME SCIENTISTS TO SUGGEST THAT CO<sub>2</sub> IS BEING TAKEN UP AND CONVERTED TO BIOMASS. BUT THAT IS VERY DIFFICULT TO CONFIRM IN STUDIES OF NATURAL ECOLOGICAL SYSTEMS SO FAR.

THE SECOND POINT FROM THE FIGURE CONCERNS THE GROWTH IN CO<sub>2</sub> EMISSION. PRIOR TO THE ARAB OIL EMBARGO, EMISSIONS GREW STEADILY AT ABOUT 4.4% PER YEAR. WHEN THE GREENHOUSE ISSUE WAS FIRST IDENTIFIED IN THE MID-1970S, THAT RATE WAS EXTRAPOLATED TO PROJECT ATMOSPHERIC CO<sub>2</sub> LEVELS WOULD DOUBLE EARLY IN THE NEXT CENTURY, SAY 2025. HOWEVER, THE REDUCED USE OF FOSSIL FUELS SINCE THEN, CAUSED FORECASTS OF DOUBLING TO MOVE OUT BY SEVERAL DECADES, SAY TILL 2075-2100. THE FIGURE SHOWS THAT THE GROWTH RATE HAS ONCE AGAIN RECOVERED TO PAST HISTORICAL LEVELS. IF THE HIGHER GROWTH PERSISTS, THE DOUBLING TIME WILL AGAIN MOVE CLOSER BY SEVERAL DECADES.

### HISTORICAL RECORD OF GLOBAL TEMPERATURE CHANGE



Noteworthy Differences  
With Greenhouse Predictions

- Recent Warming Reverses Cooling From 1940-1970s
  - 1980s Warmest Decade on Record
  - Persistent Trend Could Signal Greenhouse Warming
- US 1988 Summer Heat and Drought, A Critical Media Event
  - Not a Predicted Consequence of Greenhouse Warming
  - Due to a Natural Weather Fluctuation
  - Cited as an Example of Future Trends

THE FINAL DATA SET COVERS PAST VARIATION IN GLOBAL AVERAGE TEMPERATURE. OF COURSE, GLOBAL AVERAGE TEMPERATURE IS A STATISTICAL CONCEPT. IT CANNOT BE DIRECTLY MEASURED. THERE ARE SERIOUS ISSUES CONCERNING COMPLETENESS, ACCURACY, AND INTERPRETATION OF THIS HISTORICAL DATA. HOWEVER, THE PROBLEM IS RECEIVING A GREAT DEAL OF ATTENTION, AND MOST STUDIES SHOW RESULTS SIMILAR TO THESE.

THE DATA SHOW A RELATIVELY LARGE SCATTER OF A FEW TENTHS OF A DEGREE FROM YEAR TO YEAR. THIS "NOISE" OCCURS FROM NATURAL FLUCTUATIONS THAT ARE NOT COMPLETELY UNDERSTOOD. IT IS KNOWN THAT EVENTS LIKE VOLCANIC ERUPTIONS AND CHANGES IN OCEANIC UPWELLING (SUCH AS EL NINO), CAUSE PART OF THE VARIABILITY. THE DASHED TREND LINE ILLUSTRATES THE GENERAL BEHAVIOR. THE RECORD SHOWS AN APPARENT RISE OF ABOUT  $1/20$  C OVER THE PAST 100 YEARS.

HOWEVER, THE WARMING DOES NOT AGREE WITH MODELS BASED ON CO<sub>2</sub> VARIATIONS. IN PARTICULAR, ENHANCED GREENHOUSE MODELS PREDICT A SMOOTHLY ACCELERATING INCREASE OF TEMPERATURE WITH TIME (SHOWN IN RED). THE DATA ARE QUITE DIFFERENT. MOST NOTICEABLE IS A COOLING TREND BETWEEN THE 1930S AND LATE 1970S WHEN THE MODEL PREDICTS WARMING.

DATA ON TEMPERATURE VARIATION IN THE 1980S ARE NOW BECOMING AVAILABLE. THEY SHOW A REVERSAL OF THE RECENT COOLING TREND. IN FACT, THE 3 WARMEST YEARS ON RECORD OCCURRED IN THE 1980S. IF THIS TREND PERSISTS IT

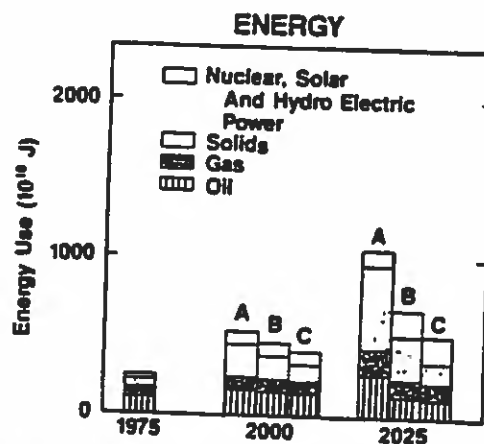


COULD SIGNAL THAT ENHANCED GREENHOUSE WARMING IS FINALLY BECOMING DETECTABLE.

THERE IS NO DOUBT THAT THE 1988 HEAT AND DROUGHT WERE A CRITICAL EVENT IN THE GREENHOUSE ISSUE, BECAUSE THEY STIRRED PUBLIC ATTENTION, AND BROUGHT HOME POTENTIAL CONSEQUENCES OF CLIMATE WARMING. HOWEVER, 1988 WAS NOT A PREDICTED CONSEQUENCE OF ENHANCED GREENHOUSE MODELS. MOST METEOROLOGISTS INTERPRET THE SUMMER AS AN INFREQUENT, BUT NOT UNEXPECTED FLUCTUATION IN WEATHER. GREENHOUSE SCIENTISTS BY AND LARGE HAVE NOT CLAIMED THE US HEAT AND DROUGHT WERE CAUSED BY ENHANCED GREENHOUSE, BUT THEY HAVE CITED IT AS AN EXAMPLE OF WHAT PEG MIGHT BRING.

SO FAR WE HAVE DISCUSSED THE HISTORICAL RECORD, AND SHOWN THE IMPORTANT DATA. HOWEVER, PEG IMPACTS OCCUR IN THE FUTURE. SO NOW WE TURN TO PROJECTIONS.

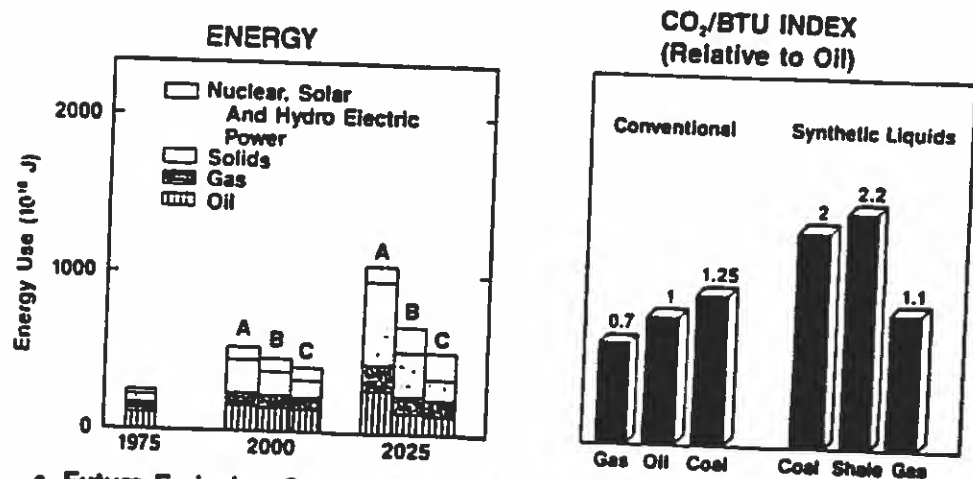
### PROJECTED SOURCES OF ENERGY AND CO<sub>2</sub> EMISSION



- Future Emission Sensitive to Forecasts of Energy Demand, Source
- Projections Differ Significantly Beyond Near Term

FORECASTS OF FUTURE LEVELS OF ATMOSPHERIC CO<sub>2</sub> BEGIN BY PROJECTING ENERGY NEEDS AND SOURCES WELL INTO THE NEXT CENTURY. THE FIGURE SHOWS THREE FORECASTS OF ENERGY DEMAND TAKEN FROM A DOE STUDY, LABELED CASE A, B, AND C. THE UNIT OF ENERGY IS 10<sup>18</sup> JOULES, WHICH IS ABOUT THE SAME AS QUADS, OR QUADRILLIONS OF BTUs. CASE B IS CLOSE TO RECENT EXXON PROJECTIONS.

### PROJECTED SOURCES OF ENERGY AND CO<sub>2</sub> EMISSION

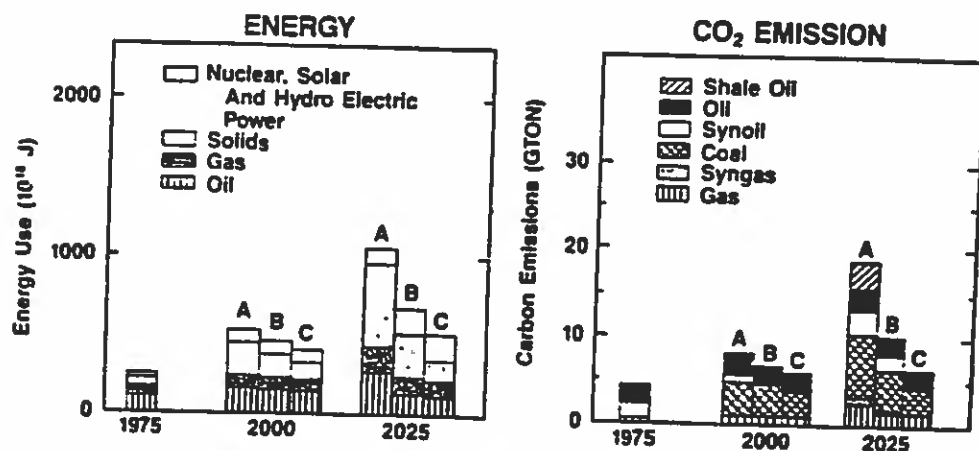


- Future Emission Sensitive to Forecasts of Energy Demand, Source
- Projections Differ Significantly Beyond Near Term

IT IS WELL KNOWN THAT FOSSIL FUELS EMPLOYED TO SATISFY THE DEMANDS, DIFFER IN THE AMOUNT OF CO<sub>2</sub> RELEASED TO PRODUCE A BTU OF ENERGY. THIS PART OF THE FIGURE COMPARES FOSSIL FUELS ON A RELATIVE SCALE WHERE EMISSIONS PER BTU FROM CONVENTIONAL OIL ARE TAKEN AS ONE. THEN, GAS IS 0.7 AND COAL IS 1.25. WE ALSO SHOW THE INDEX VALUES FOR SYNTHETIC LIQUIDS. SYNTHETIC LIQUIDS FROM COAL AND SHALE RESULT IN GREATER CO<sub>2</sub> EMISSIONS. THE EXTRA CO<sub>2</sub> IS GENERATED IN THE MANUFACTURING PROCESS. ESPECIALLY FOR SYNTHETICS FROM

COAL AND SHALE THE CO<sub>2</sub> FACTOR IS SENSITIVE TO THE RAW MATERIAL AND PROCESS ROUTE. LIQUIDS DERIVED DIRECTLY FROM GAS HAVE SIGNIFICANTLY LOWER CO<sub>2</sub> INDICES.

### PROJECTED SOURCES OF ENERGY AND CO<sub>2</sub> EMISSION

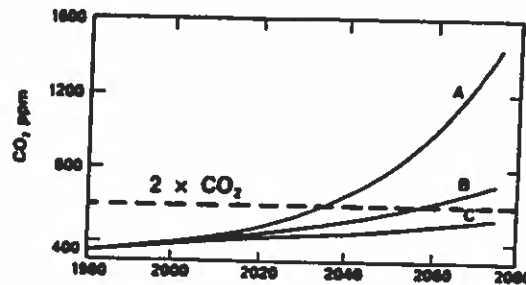


- Future Emission Sensitive to Forecasts of Energy Demand, Source
- Projections Differ Significantly Beyond Near Term

FOR EACH ENERGY DEMAND CASE... (A, B, & C)... THIS CO<sub>2</sub> GENERATION INDEX CAN BE USED TO COMPUTE CO<sub>2</sub> EMISSIONS AS SHOWN IN THE FINAL FIGURE. CASE A WITH THE GREATEST ENERGY DEMAND ALSO PRODUCES MUCH HIGHER CO<sub>2</sub> EMISSIONS, SINCE IT RELIES ON HIGH CO<sub>2</sub> PRODUCING FUELS FROM SYNTHETICS. OVERALL FORECASTS DIFFER WIDELY BEYOND THE NEAR TERM. EXTENDED OUT TO 2100 THEY VARY BY FACTORS OF 20 IN CO<sub>2</sub> EMISSION LEVELS.

## PROJECTED GROWTH OF ATMOSPHERIC CO<sub>2</sub>

- Combine Forecasts: Economic Growth, Energy Use, CO<sub>2</sub> Growth



- Atmospheric CO<sub>2</sub> Doubles (600 ppm)

— Case A: 2030  
— Case B: 2060  
— Case C: 2100

BY COMBINING THESE THREE TYPES OF PROJECTIONS FOR THE FUTURE...

- TOTAL ENERGY CONSUMPTION
- CO<sub>2</sub> EMISSION FACTORS FOR VARIOUS FOSSIL FUELS

AND

- DISTRIBUTION OF FOSSIL FUEL ENERGY CONSUMPTION BY RESOURCE...

IT IS POSSIBLE TO FORECAST FUTURE LEVELS OF ATMOSPHERIC CO<sub>2</sub>. THE PROJECTIONS SHOW DOE FORECASTS FOR THE 3 CASES THROUGH THE YEAR 2080.

IN THESE FORECASTS THE CO<sub>2</sub> DOUBLING TIME IS A CONVENIENT BENCHMARK TO MEASURE CO<sub>2</sub> BUILD-UP. (IT IS THE LEVEL CONSIDERED IN MOST CLIMATE SIMULATIONS OF THE GREENHOUSE EFFECT.) HOWEVER, THERE IS NOTHING MAGICAL ABOUT DOUBLING ITSELF. TAKING THE DOUBLING LEVEL TO BE 600-700 PPM, THE VARIOUS CASES LEAD TO A DOUBLING BETWEEN 2030 AND 2100 AS INDICATED.

## POTENTIAL CLIMATE IMPACT FROM CO<sub>2</sub>: NEXT 100 YEARS

"CHANGING CLIMATE", NATIONAL RESEARCH COUNCIL 1983

- Temperature
  - Global Mean Temperature Increase ... 1.5 – 4.5°C
  - Greater Warming in Polar Regions (2–3x)
- Sea Level/Sea Ice
  - Coverage and Thickness of Sea Ice/Glaciation Will Decrease
  - Sea Level Rise (Meltwater + Thermal Expansion) ... 70 cm
- Natural Ecosystems and Agriculture
  - Regional Climate Change: Temperature, Hydrology
  - Enhanced Productivity From Increased CO<sub>2</sub>
  - Global Net Effect Uncertain

THESE CO<sub>2</sub> PROJECTIONS ARE USED IN CURRENT CLIMATE MODELS TO PREDICT IMPORTANT CHANGES OVER THE NEXT 100 YEARS. THIS SET OF RESULTS IS TAKEN FROM THE NATIONAL RESEARCH COUNCIL (NRC) REPORT "CHANGING CLIMATE".

CONSENSUS PREDICTIONS CALL FOR WARMING BETWEEN 1.5-4.5 °C FOR DOUBLED CO<sub>2</sub> WITH GREATER WARMING AT THE POLES. NOTE THAT THESE NUMBERS REFLECT THE RANGE PRODUCED BY AVAILABLE MODELS. NO ONE KNOWS HOW TO EVALUATE THE ABSOLUTE UNCERTAINTY IN THE NUMBERS.

THE EXTENT AND THICKNESS OF GLACIERS ARE PREDICTED TO DECREASE, LEADING TO SEA LEVEL RISE. THE NRC REPORT CHOSE A MOST LIKELY VALUE OF 70 CM SEA LEVEL RISE. OTHER PREDICTIONS SUGGEST A BROADER RANGE FROM 30-200 CM. THE RISE OCCURS BOTH FROM A LARGER AMOUNT OF WATER IN THE OCEANS, AND FROM THERMAL EXPANSION.

FINALLY, CLIMATE CHANGE AND HIGHER LEVELS OF ATMOSPHERIC CO<sub>2</sub> AFFECT AGRICULTURE AND ECOSYSTEMS. THERE ARE TWO ASPECTS. FIRST, THE DIRECT EFFECT OF CLIMATE CHANGE ALTERS THE LENGTH OF THE GROWING SEASON AND THE AVAILABILITY OF WATER. SECOND, NEARLY ALL PLANTS GROW MORE RAPIDLY, AND USE LESS WATER, IN A HIGH CO<sub>2</sub> ENVIRONMENT. THE SECOND EFFECT CAN BE QUITE POSITIVE FOR MANAGED AGRICULTURE.

MODELS CANNOT YET PREDICT REGIONAL CLIMATE CHANGE WITH MUCH ACCURACY. I AM SURE YOU HAVE ALL HEARD THAT THE US MID-WEST MAY BECOME A DUST BOWL FROM ENHANCED GREENHOUSE, WHILE RUSSIA MAY BECOME MORE FRUITFUL. THAT IS A PROJECTION OF SOME MODELS, BUT OTHERS SHOW THE OPPOSITE.

THE CLIMATE MODEL IMPACTS OF PEG ARE NOT ALL NEGATIVE. THEY AFFECT DIFFERENT PARTS OF THE GLOBE UNEQUALLY. THE MODELS PREDICT VARIOUS WINNERS AND LOSERS.

THIS COMPLETES THE GREENHOUSE SCIENCE DISCUSSION.

SUMMARIZING:

DATA CONFIRM THAT

- GREENHOUSE GASES ARE INCREASING IN THE ATMOSPHERE.
- FOSSIL FUELS CONTRIBUTE MOST OF THE CO<sub>2</sub>...BUT DEFORESTATION IS ALSO SIGNIFICANT.

AND

- HISTORICAL TEMPERATURES SHOW ONLY SLIGHT WARMING...NOT ENOUGH TO CONFIRM ENHANCED GREENHOUSE. THAT'S ALL THE DATA.

PROJECTIONS SUGGEST

- SIGNIFICANT CLIMATE CHANGE WITH A VARIETY OF REGIONAL IMPACTS.

AND

- SEA LEVEL RISE WITH GENERALLY NEGATIVE CONSEQUENCES.

FINALLY, THE SIZE AND TIMING OF IMPACTS ARE UNCERTAIN.

#### POTENTIAL ENHANCED GREENHOUSE

#### PLAYERS...

- US  
CONGRESS/PRESIDENT  
EPA/DOE/STATE  
NOAA/NASA/NSF  
AND THE  
MEDIA
- UN  
GENERAL ASSEMBLY -  
"WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT"  
UNEP/WMO
- CANADA  
PRIME MINISTER  
FEDERAL ENVIRONMENTAL MINISTRY
- INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS
- EEC
- OECD
- ENVIRONMENTAL GROUPS

THE KEY PLAYERS ON PEG ARE IN THE US AND UN. IN THE US, CONGRESS IS VERY INTERESTED. SENATORS LIKE WIRTH, MITCHELL, BAUCUS, AND GORE HAVE VERY HIGH PROFILES. PRESIDENT BUSH HAS COMMITTED TO CONVENE A GLOBAL GREENHOUSE CONFERENCE. WITHIN THE ADMINISTRATION, THE PLAYERS ARE EPA (WHICH HAS A PARTICULARLY CRITICAL ROLE THROUGH ITS INTERNATIONAL ACTIVITIES), DOE (WHICH SPONSORED AN EXTENSIVE REVIEW OF THE SUBJECT COMPLETED IN 1985), AND THE STATE DEPARTMENT (WHOSE INTERESTS ARE DIRECTED TOWARDS INTERNATIONAL TREATIES AND CONVENTIONS). IN ADDITION, TECHNICAL AGENCIES INCLUDING NOAA, NASA, AND NSF HAVE SIGNIFICANT ROLES...AND, OF COURSE, THE MEDIA IS VERY ACTIVE.

ALL OF THESE EFFORTS ARE ESTABLISHING LINKS WITH OTHER NATIONAL AND INTERNATIONAL INTERESTS...ESPECIALLY IN THE UN WHICH HAS DEVOTED A GREAT DEAL OF EFFORT TO PEG. THE GENERAL ASSEMBLY ESTABLISHED A WORLD-WIDE COMMISSION HEADED BY MME. GRO BRUNDTLAND (PRIME MINISTER OF NORWAY) TO EVALUATE PROBLEMS OF ENVIRONMENTAL PROTECTION AND ECONOMIC DEVELOPMENT. THE COMMISSION'S REPORT..."OUR COMMON FUTURE"...CONTAINS A HEAVY DOSE OF GREENHOUSE CONCERNS...ON CLIMATE, AGRICULTURE, ENERGY...AND LISTS IT AS THE #1 ENVIRONMENTAL PROBLEM WE FACE. THE GENERAL ASSEMBLY HAS DIRECTED ALL OF ITS AGENCIES TO DEVELOP SPECIFIC PLANS TO DEAL WITH PEG.

THE UNITED NATIONS ENVIRONMENTAL PROGRAM (UNEP) IS ONE OF THESE AGENCIES AND IT HAS



MADE PEG ITS #1 PRIORITY. UNEP...LIKE EPA HAS A CRITICAL ROLE...HAVING BEEN DIRECTED TO DEVELOP DETAILED PLANS WITH THE WORLD METEOROLOGICAL ORGANIZATION (WMO) FOR ACTION PROGRAMS AND POLICY PROPOSALS TO BE RECOMMENDED TO THE GENERAL ASSEMBLY.

THERE ARE NUMEROUS OTHER PLAYERS. THE CANADIANS, INCLUDING THEIR PRIME MINISTER AND FEDERAL ENVIRONMENTAL MINISTRY, HAVE BEEN...PERHAPS...THE MOST OUTSPOKEN GOVERNMENT IN RESPONDING TO THE NEED FOR GREENHOUSE LIMITATIONS. THEY SPONSORED A WORLD CONFERENCE ON PEG DURING THIS PAST JUNE...WHICH CALLED FOR 20% REDUCTION IN CO2 EMISSIONS BY 2010 WITH AN OVERALL GOAL OF 50% REDUCTION...AND A TAX ON FOSSIL FUELS TO FUND ALTERNATE ENERGY DEVELOPMENT.

THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS (ICSU) IS PROVIDING A FORUM FOR WORLD-WIDE SCIENTIFIC EFFORTS UNDER THE BANNER OF THE "INTERNATIONAL BIOPHYSICAL YEAR". THE EUROPEAN ECONOMIC COMMUNITY (EEC) IS PURSUING ITS POSITION AND DEVELOPED COUNTRIES IN THE OECD HAVE ESTABLISHED ACTIVITIES TO PARTICIPATE IN THE EXPECTED DEBATE.

OF COURSE, NUMEROUS ENVIRONMENTAL GROUPS...INCLUDING HIGH PROFILE ORGANIZATIONS LIKE THE GREENS, WORLD RESOURCES INSTITUTE, AND NATIONAL RESOURCES DEFENSE COUNCIL...HAVE NOW INVESTED A LOT OF TIME AND EFFORT IN EXPERTISE RELATED TO ENERGY AND GREENHOUSE. HAVING INVESTED SIGNIFICANT

**EFFORT, THEY NEED...AND INTEND...TO HAVE  
SIGNIFICANT IMPACT.**

**SCHEDULED ACTIVITIES - PEG**

**US**

- **INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE  
(WITH WMO/ICSU) 1988**
- **EPA REPORTS ON 1988**
  - **POTENTIAL CONSEQUENCES FOR US/WORLD**
  - **MITIGATION/STABILIZATION APPROACHES**
- **DOE 1989**
  - **ASSESSMENT OF R&D ON ALTERNATE ENERGY**
  - **INVENTORY OF GREENHOUSE GASES**
  - **ANALYSIS OF PRIVATE SECTOR OPTIONS**
  - **POLICY OPTIONS TO LIMIT EMISSIONS**
- **US/INTERNATIONAL SCIENCE ASSESSMENT 1990**

**UN**

- **COORDINATE WORLDWIDE SCIENTIFIC ASSESSMENT WMO/ICSU 1990**
- **REGIONAL IMPACT ASSESSMENTS 1990**
- **POLICY OPTIONS TO LIMIT CLIMATE CHANGE 1990**
- **INTERNATIONAL CONVENTION TO LIMIT CLIMATE CHANGES MID '90'S**

**THE INTENSITY OF THESE EFFORTS IS REFLECTED  
IN THE SLATE OF ACTIVITIES CURRENTLY SCHED-  
ULED. FOR EXAMPLE, IN '88 THE US, THROUGH  
NOAA AND NASA, SET UP AN INTERGOVERNMENTAL  
CLIMATE PANEL WITH WMO AND ICSU TO PROMOTE  
LIAISON BETWEEN GOVERNMENTS...AND EPA WAS TO  
REPORT TO CONGRESS ON BOTH POTENTIAL CONSE-  
QUENCES OF PEG FOR THE US/WORLD AND...  
MITIGATION/STABILIZATION APPROACHES TO LIMIT  
CLIMATE CHANGE. THIS REPORT IS NOW DUE IN  
1989. DOE WILL BE VERY BUSY. IN 1989, IT**

IS DUE TO DEVELOP REPORTS ON VARIOUS ASPECTS OF PEG INCLUDING:

- ASSESSING ALTERNATE ENERGY R&D
- CATALOGUING GREENHOUSE GASES
- ANALYZING ENERGY OPTIONS FOR THE PRIVATE SECTOR

AND

- EVALUATING POLICY OPTIONS FOR LIMITING CO<sub>2</sub> EMISSIONS

FINALLY, NSF IS PLANNING A US/INTERNATIONAL SCIENCE ASSESSMENT BY 1990.

THE UN HAS RECENTLY COMMISSIONED A WORLDWIDE SCIENTIFIC ASSESSMENT DESIGNATING WMO TO WORK CLOSELY WITH ICSU. BY THE WAY, NSF WILL ALSO COORDINATE CLOSELY WITH THIS EFFORT IN DEVELOPING ITS VIEWS. REGIONAL IMPACT STUDIES ARE BEING SET UP USING CLIMATE MODELS TO PROJECT THE VARIOUS WINNERS AND LOSERS AS RAINFALL, WIND, STORMS, AND SEA LEVEL PATTERNS CHANGE. THIS COULD BE ESPECIALLY CONTENTIOUS BECAUSE OF THE WIDE ROOM FOR INTERPRETATION IN APPLYING THE MODELS AND THE ENORMOUS POTENTIAL POLITICAL CONSEQUENCES. CONCURRENTLY, UNEP WILL DEVELOP ITS VIEW OF POLICY OPTIONS TO LIMIT CLIMATE CHANGE. ALL OF THESE ACTIVITIES ARE PLANNED FOR COMPLETION IN 1990. UNEP HAS BEEN URGED TO AIM FOR AN INTERNATIONAL CONVENTION ON PEG BY ABOUT 1995. HOWEVER, THIS TARGET DATE SEEMS TO BE ADVANCING TOWARDS 1992.

GIVEN, THE...

- COMPLEXITY OF THE SCIENCE
  - ENORMOUS POTENTIAL GLOBAL IMPACTS
  - DIVERSITY OF THE PLAYERS
- AND
- INTENSITY OF THEIR ACTIVITIES...

WHERE IS ALL THIS HEADED? I BELIEVE THERE IS A PATTERN...AND IT'S ROOTED IN THE EVOLUTION OF THE JUST-COMPLETED MONTREAL PROTOCOLS TO PROTECT THE STRATOSPHERIC O<sub>3</sub> LAYER BY LIMITING MAN-MADE CFCs.

# STRATOSPHERIC OZONE/PEG ANALOGY

## OZONE LAYER

## ENHANCED GREENHOUSE

'74	✓	ATMOSPHERIC CHEM/PHYS	✓	'76
	✓	GROWTH IN [CFC'S] / [CO <sub>2</sub> ] & [TRACE GASES]	✓	
	✓	INDUSTRIAL SOURCES	✓	
	✓	MODELS: END EFFECT PROJECTIONS	✓	
	✓	CONCEPT OF "DELAY"	✓	
	✓	ENVIRONMENTAL CAUSE	✓	
	✓	INTERNATIONAL OWNERSHIP	✓	
	✓	US/UN AXIS	✓	
	✓	CRITICAL EVENT	✓	
	✓	CALL FOR ACTION	?	
		<u>VIENNA CONVENTION</u>	?	
'87		<u>MONTREAL PROTOCOLS</u>	?	

ABOUT 20 YEARS AGO, THE ATMOSPHERIC CHEMISTRY AND PHYSICS BEGAN WITH CONCERNS OVER THE EFFECT OF SUPERSONIC TRANSPORTS ON THE O<sub>3</sub> LAYER. AS THESE FEARS ABATED...IN 1974... SOME SCIENTISTS' LABORATORY TESTS INDICATED THAT THE VERY STABLE CLASS OF MAN-MADE CHEMICALS (CFCs) BREAK DOWN UNDER THE KIND

OF INTENSE UV RADIATION THAT IS PRESENT IN THE STRATOSPHERE...WITH THE RESULTING CL AND BR ATOMS ATTACKING AND DESTROYING O<sub>3</sub>.

SUBSEQUENTLY, IT WAS ESTABLISHED THAT THE CFC CONCENTRATIONS WERE INCREASING IN THE STRATOSPHERE. THESE CFCs, OF COURSE, WERE EASILY TRACED TO MAN-MADE SOURCES AND INDUSTRIAL APPLICATIONS.

EXTENSIVE MODELING EXERCISES PREDICTED...

- THE LONG TERM RATE OF O<sub>3</sub> LAYER DETERIORATION
- THE RESULTING INCREASED UV PENETRATION OF THE EARTH'S ATMOSPHERE  
AND
- THE SERIOUS POTENTIAL REPERCUSSIONS LIKE INCREASED HUMAN CANCER RATES AND PLANT DAMAGE

NOW THESE PREDICTED EFFECTS WERE WELL INTO THE FUTURE. SO A CRUCIAL STEP WAS THE INTRODUCTION OF "A DELAY CONCEPT" BASED ON THE UNUSUAL CHEMICAL STABILITY OF CFCs IN THE LOWER ATMOSPHERE AND THE VERY LONG TRANSPORT TIMES FOR CFCs TO REACH THE UPPER STRATOSPHERE. THE REASONING WAS...THERE WAS AN ALREADY COMMITTED O<sub>3</sub> LAYER DETERIORATION BASED ON CFCs ALREADY "IN THE PIPELINE". THIS GAVE RISE TO AN ENVIRONMENTAL CAUSE WHICH WAS QUICKLY ADOPTED AS AN INTERNATIONAL ISSUE. THE PLAYERS WERE BASICALLY SIMILAR TO THOSE ORGANIZING AROUND THE CURRENT

GREENHOUSE ISSUE...PRIMARILY IN THE US AND UN. WHEN THE US BECAME ACTIVELY INVOLVED...INITIATING COOPERATION WITH THE UN TO LIMIT WORLDWIDE CFC PRODUCTION AND SALES...ALL OF THE ELEMENTS WERE IN PLACE.

BUT WITH ALL OF THIS, PROGRESS BEGAN TO LANGUISH AND THE EFFORT MIGHT WELL HAVE FOUNDERED, EXCEPT FOR THE DISCOVERY OF THE SO-CALLED "O<sub>3</sub> LAYER HOLE" OVER ANTARCTICA. THIS WAS A MOST CRITICAL EVENT - ALTHOUGH ITS EXACT RELEVANCE TO CFC RELATED O<sub>3</sub> LAYER DETERIORATION REMAINS UNEXPLAINED. IT RE-ENERGIZED THE EFFORT AND DIRECTLY LED TO A "CALL FOR ACTION" AND THE VIENNA CONVENTION. SHORTLY THEREAFTER...IN 1987...THE MONTREAL PROTOCOLS TO LIMIT CFCs WITH A PHASED 50% REDUCTION BY THE TURN OF THE CENTURY WERE APPROVED AND ARE EXPECTED TO BE ADOPTED. I SHOULD ADD THAT IN 1988...JUST WITHIN THE PAST 6 MONTHS OR SO...THERE IS FOR THE FIRST TIME CONVINCING SCIENTIFIC EVIDENCE THAT O<sub>3</sub> LAYER DETERIORATION HAS BEEN DETECTED. SO THAT AFTER THE FACT...SOME ACTION SEEMS JUSTIFIED.

NOW, I HOPE FROM THE MATERIAL COVERED ON GREENHOUSE SO FAR...IT IS CLEAR THAT WE HAVE ADVANCED THROUGH SIMILAR STAGES. A CRITICAL EVENT OCCURRED WITH THE "LONG HOT SUMMER OF '88". ALTHOUGH MOST RESPONSIBLE SCIENTISTS BELIEVE THIS WAS DUE TO NATURAL FLUCTUATIONS IN WEATHER PATTERNS...IT HAS DRAWN MUCH ATTENTION TO THE POTENTIAL PROBLEMS AND WE'RE STARTING TO HEAR THE INEVITABLE CALL FOR ACTION. EXACTLY WHAT HAPPENS NOW IS NOT

**CLEAR...BUT THIS CRITICAL EVENT HAS ENERGIZED THE GREENHOUSE EFFORT AND RAISED PUBLIC CONCERN OVER PEG.**

**SOME KEY PERCEPTIONS/MISCONCEPTIONS...**

- "PEG" IS PART OF/CLOSELY LINKED TO "O<sub>3</sub> LAYER PROTECTION"
- ENOUGH RESEARCH HAS BEEN DONE
  - EXISTENCE OF PEG IS NOW ESTABLISHED
  - ADVANCING THE SCIENCE WILL TAKE TOO LONG
- '88 SUMMER WAS DUE TO PEG
- CAN'T TOLERATE DELAY
- NEED POLICY DEVELOPMENT NOW
- PROJECTED SHIFTS IN WEATHER WILL FEATURE BIG WINNERS AND LOSERS WITH MAJOR POLITICAL IMPLICATIONS
- DEVELOPED COUNTRIES WILL SHIFT RESOURCES TO DEVELOPING COUNTRIES
- NUCLEAR AND/OR RENEWABLE ENERGY RESOURCES CAN SOLVE THE PROBLEM

**OVERALL...**

- RISK FROM PEG CLIMATE CHANGES IS NOT ACCEPTABLE...  
MUST DEVELOP (IMPLEMENT) CONTROL POLICIES NOW

**IN FACING THIS REALITY, THERE ARE SOME KEY PERCEPTIONS AND MISCONCEPTIONS WE'LL HAVE TO DEAL WITH. THE FIRST MISCONCEPTION IS THAT PEG AND O<sub>3</sub> LAYER ARE SOMEHOW THE SAME PROBLEM...OR AT LEAST CLOSELY LINKED. THIS IS PARTICULARLY DANGEROUS BECAUSE THE TWO PROBLEMS ARE, IN FACT, VERY DIFFERENT AND EFFECTIVE SOLUTIONS ARE BOUND TO BE VERY DIFFERENT...BANNING A SINGLE CLASS OF MAN-MADE CFC CHEMICALS IS VERY DIFFICULT...BUT PALES BY COMPARISON TO THE DIFFICULTIES OF APPLYING SIMILAR APPROACHES TO LIFE CYCLE GASES LIKE CO<sub>2</sub> AND WATER.**

THE SECOND MISCONCEPTION IS THAT ENOUGH RESEARCH ON THE BASIC PROBLEM HAS BEEN DONE. FAILURE TO UNDERSTAND THE NEED FOR SUBSTANTIAL ADVANCES IN THE SCIENCE TO REDUCE THE UNCERTAINTY AND EXTREME VARIABILITY IN THE PROJECTIONS CAN LEAD TO PREMATURE LIMITATIONS ON FOSSIL FUELS.

USING THE '88 SUMMER WEATHER PATTERNS AS PART OF THIS ARGUMENT...THE THIRD MISCONCEPTION...IS SIMPLY INCORRECT.

ARGUMENTS THAT WE CAN'T TOLERATE DELAY AND MUST ACT NOW CAN LEAD TO IRREVERSIBLE AND COSTLY DRACONIAN STEPS.

PROJECTING PEG INDUCED CLIMATIC REGIONAL WINNERS AND LOSERS...AND COMPETITION BETWEEN DEVELOPED AND DEVELOPING COUNTRIES IN RATIONING ENERGY TO LIMIT PEG...COULD EASILY DOMINATE ANY DEBATE AND MAKE RATIONAL CO-OPERATION LESS LIKELY.

THERE HAVE BEEN DRAMATIC SHIFTS IN ATTITUDES TOWARDS NUCLEAR ENERGY BY ENVIRONMENTAL GROUPS BECAUSE OF THEIR CONCERNS OVER PEG. FURTHERMORE, RENEWABLE ENERGY ADVOCATES HAVE TRADITIONALLY OVERSTATED CAPABILITIES. THESE BOTH TEND TO ENCOURAGE A PRECIPITOUS SHIFT TO ALTERNATE ENERGY AND UNDERSTATE THE CONSIDERABLE DIFFICULTIES WHICH MUST BE OVERCOME.



## WHAT'S NEXT

### Expect:

- Continued Pressure to...  
OVERSTATE SCIENTIFIC UNDERSTANDING
- Prominent Media Role to...  
INCREASE PUBLIC CONCERNS
- More Initiatives to...  
INCREASE PACE OF INTERNATIONAL NEGOTIATIONS



**'Crisis Mentality'**

### Rational Responses Require:

- Efforts to...  
EXTEND THE SCIENCE
- Emphasis on...  
COSTS/POLITICAL REALITIES



**'Adaptation'**

AS FOR "WHAT'S NEXT"...WE CAN EXPECT CONTINUED PRESSURE TO OVERSTATE CURRENT SCIENTIFIC UNDERSTANDING. THE MEDIA ROLE...ALREADY PROMINENT...IS LIKELY TO INCREASE PUBLIC AWARENESS AND CONCERN, AND THERE WILL BE CONTINUING INITIATIVES TO EXTEND INTERNATIONAL NEGOTIATIONS. AS THE DEGREE OF THESE EFFORTS EXCEED UNDERSTANDING (OR ABILITY TO RESPOND CONSTRUCTIVELY)...THERE IS A TENDENCY TOWARDS A "CRISIS MENTALITY." MEANWHILE, MORE RATIONAL RESPONSES WILL REQUIRE EFFORTS TO EXTEND THE SCIENCE AND INCREASE EMPHASIS ON COSTS AND POLITICAL REALITIES TO FRAME "ADAPTIVE" MEASURES WHICH ARE DOABLE AND MOVE TOWARDS CONSTRUCTIVE OPTIONS.

### EXXON'S POSITION

- IMPROVE UNDERSTANDING
  - Extend the Science
  - Include the Costs/Economics
  - Face the Socio-Political Realities
- STRESS ENVIRONMENTALLY SOUND ADAPTIVE EFFORTS
  - Support Conservation
  - Restrict CFCs
  - Improve Global Re/De Forestation

TO BE A RESPONSIBLE PARTICIPANT AND PART OF THE SOLUTION TO PEG, EXXON'S POSITION SHOULD RECOGNIZE AND SUPPORT 2 BASIC SOCIETAL NEEDS. FIRST...TO IMPROVE UNDERSTANDING OF THE PROBLEM...NOT JUST THE SCIENCE...BUT THE COSTS AND ECONOMICS TEMPERED BY THE SOCIO-POLITICAL REALITIES. THAT'S GOING TO TAKE YEARS (PROBABLY DECADES). BUT THERE ARE MEASURES ALREADY UNDERWAY THAT WILL IMPROVE OUR ENVIRONMENT IN VARIOUS WAYS...AND IN ADDITION REDUCE THE GROWTH IN GREENHOUSE GASES. THAT'S THE SECOND NEED INCLUDING THINGS LIKE ENERGY CONSERVATION, RESTRICTION OF CFC EMISSIONS, AND EFFORTS TO INCREASE THE GLOBAL RATIO OF Re/De FORESTATION. OF COURSE, WE'LL NEED TO DEVELOP OTHER RESPONSE OPTIONS...IMPLEMENTING MEASURES WHEN THEY ARE COST EFFECTIVE IN THE NEAR TERM AND PURSUING NEW TECHNOLOGIES FOR THE FUTURE.